

***HPEC 2004 Panel Session:
Amending Moore's Law for Embedded Applications***

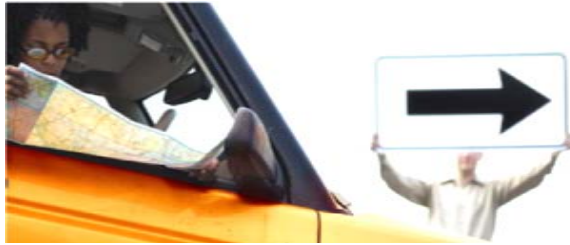
**Roadmapping the Semiconductor Industry:
Are we reaching the end of the road?**

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September 29, 2004

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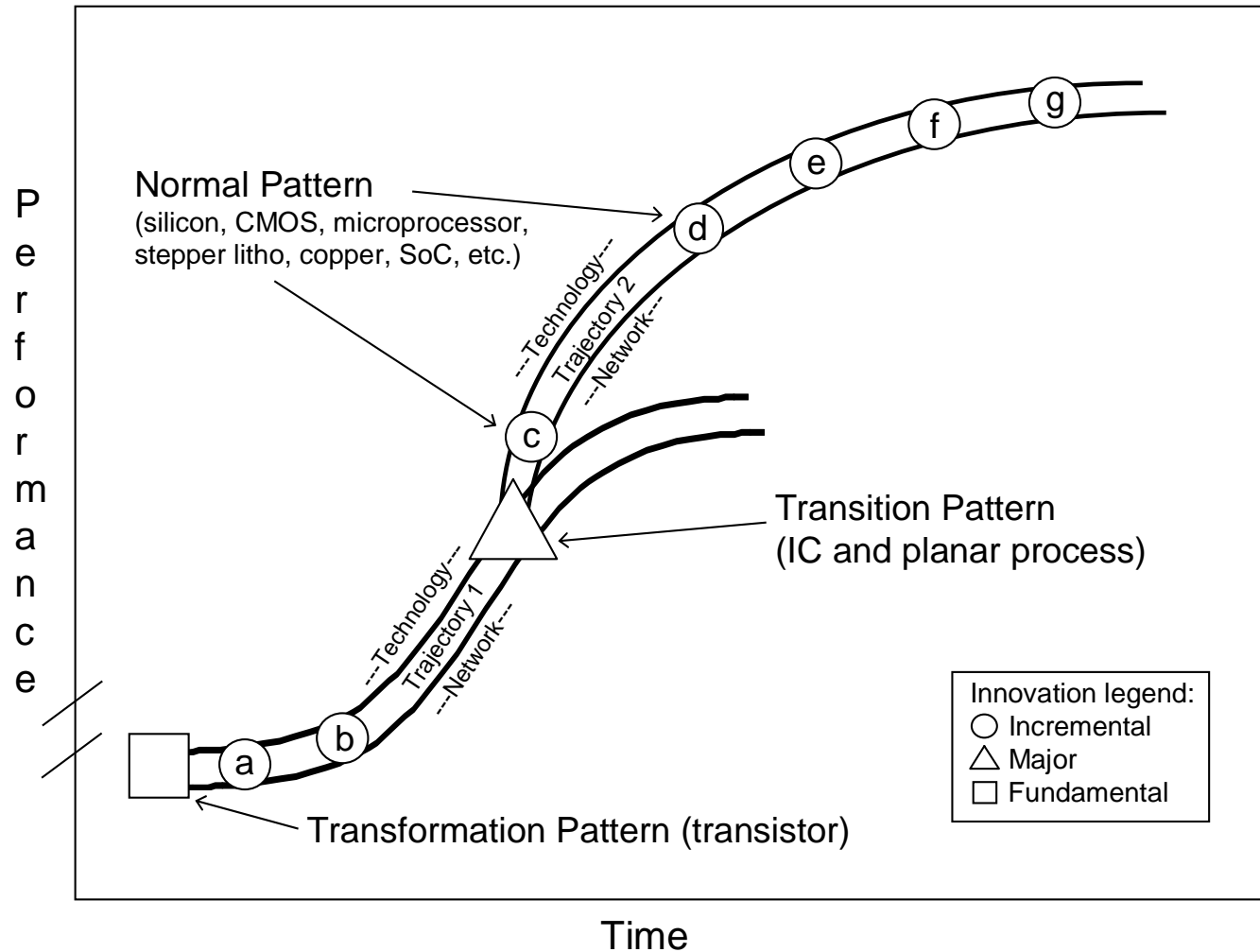
The Road to Technology Roadmaps



TECHNOLOGY ROADMAPS: Implications for Innovation, Strategy, and Policy

- **Personal experience in computer service since mid 1970s: from mainframe to minicomputer to personal computer**
 - observed miniaturization but had no “label” for trend
 - first introduced to “Moore's Law” in PhD Special Topics course
 - wrote term paper on Moore's Law, later published in *IEEE Spectrum* (June 1997) - met Gordon Moore as part of research
- **Proposed Intel case study as dissertation topic (i.e., coordinating effect of Moore's Law) but did not work**
- **Request to Sematech to study SIA Roadmap (Moore's Law "Insurance")**
 - formal research arrangement with ITRS Managing Editor
 - met Ron Kostoff at ONR and co-authored S&T Roadmap paper (*IEEE TEM*, May 2001); got connected w/ other “roadmappers”

Rycroft/Kash Innovation Patterns



Moore's Law and the ITRS

Chapter 8: Moore's Law: Basis for Industrial Cadence

- Simple observation (plot) becomes an imperative (law)
- Fundamentally defines industry, part of its culture
- Made possible by upstream SM&E capabilities and permeates downstream user capabilities
- Basis for Roadmap
- Appendix includes 8yr retrospective and new formulations (e.g., as learning curve)

What *is* Moore's Law?

"The Roadmap is just Moore's Law, heavily decorated."

- Sonny Maynard, SRC VP

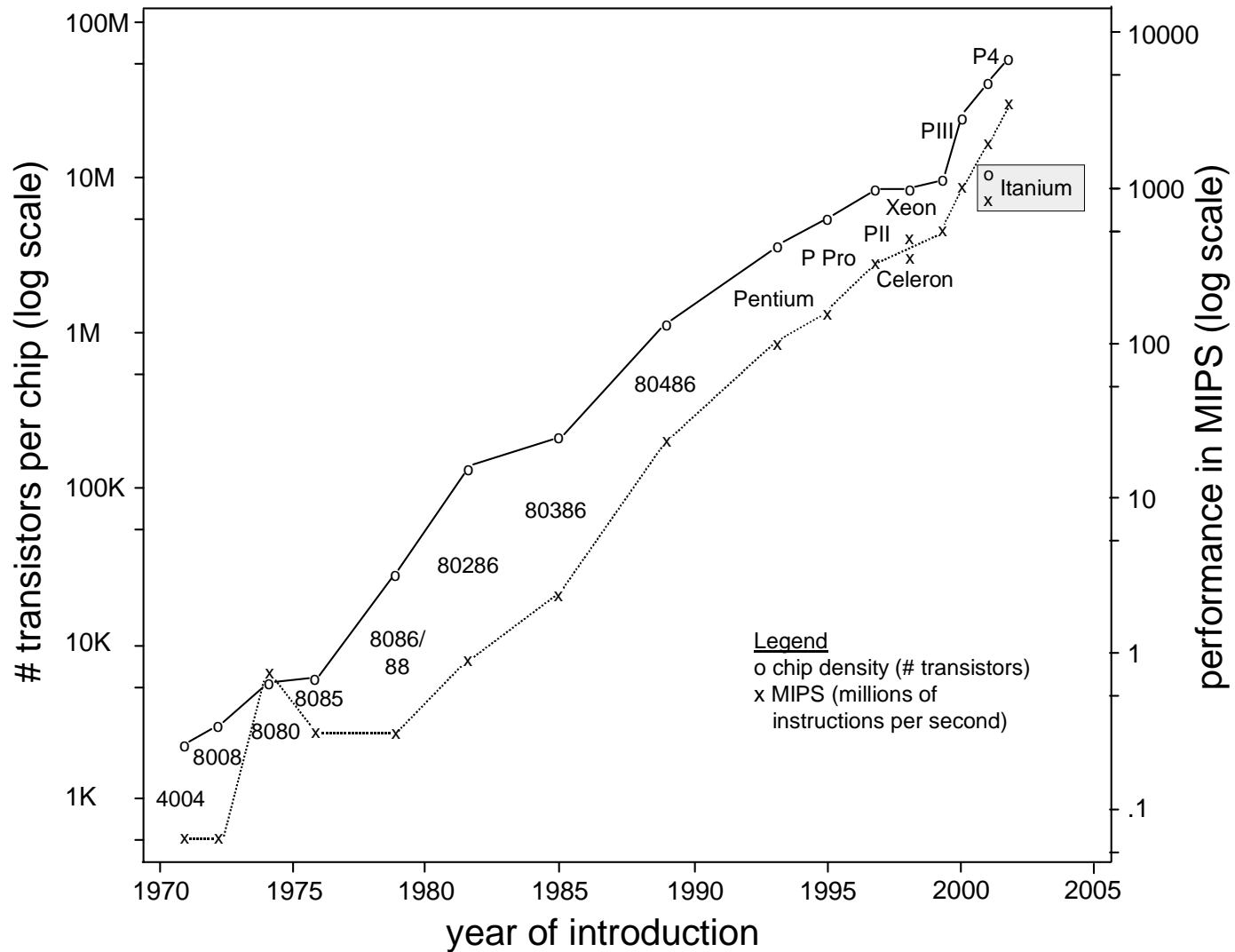
"We don't adhere to Moore's Law for the hell of it. It's a fundamental expectation that everybody at Intel buys into... We simply don't accept the growing complexity of the challenge as an excuse not to keep it going."

- Craig Barrett, Intel CEO

"Moore's Law is not a law; it is an act of will."

- Chris Mack, KLA-Tencor VP

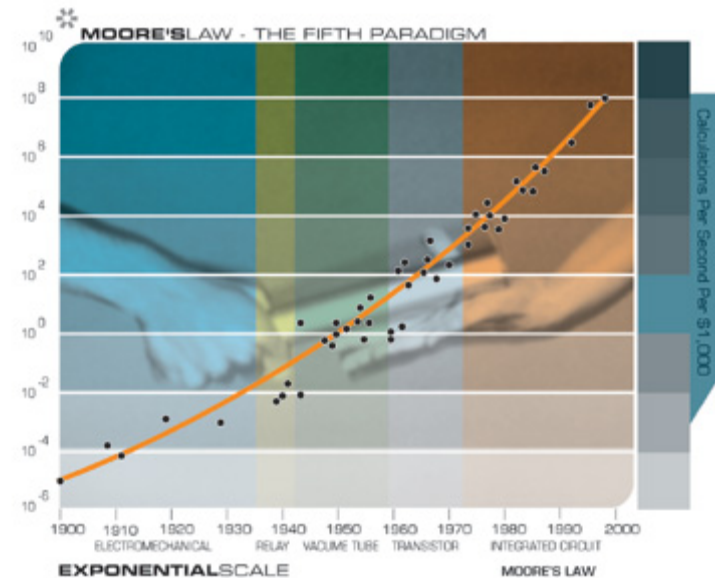
Intel Microprocessor Evolution



A Retroactive Look at Moore's Law

Year	Feature Size	Technology
1900	1 inch	Telegraph wires
1912	1/4 inch	Electromechanical relays
1924	1/16 inch	de Forest Audion
1936	16 mils	Triode vacuum tubes
1948	4 mils	Miniature vacuum tubes
1960	1 mil (25 μm)	Planar transistor

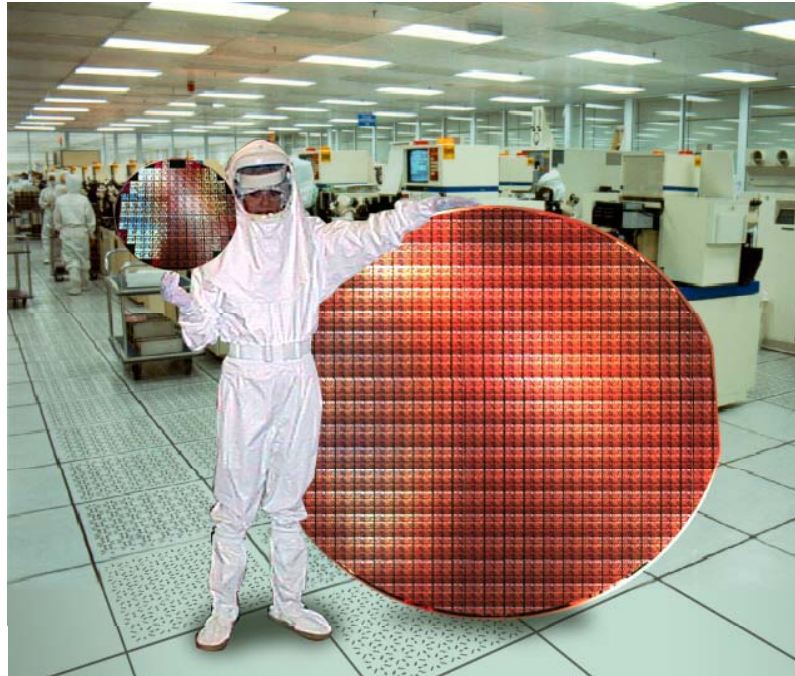
Source: Chris A. Mack, "The End of the Semiconductor Industry as We Know It," Paper presented at SPIE 2003, February 2003, Table 1, 5. Data taken from Raymond Kurzweil, *The Age of Spiritual Machines*, New York: Penguin Books, 1999.



Source: Raymond Kurzweil, "The Law of Accelerating Returns," March 7, 2001,
<http://www.kurzweilai.net/articles/art0134.html>

Gordon Moore: *No Exponential is Forever ... but We Can Delay “Forever,”* ISSC03

Projected 2000 Wafer, circa 1975



Moore was not always accurate

Source: www.intel.com/research/silicon/mooreslaw.htm, Slide #12

Blind Extrapolation (Mack from 1995)

**Mack's Roadmap for
Semiconductor Production in
the Year 2025**

- DRAM Chip: 64Tb (that's terabits, folks!)
- Minimum CD: 100Å (that's about 5 photoresist molecules)
- CD Control Spec: ± 10 Å (that's \pm one-half of a photoresist molecule)
- Overlay Spec: 30Å
- Chip Size: 3 x 6 in. (120 cm²)
- Wafer Size: 32 in.
- Fab Cost: \$1 Trillion
- Chip Price: \$1,000

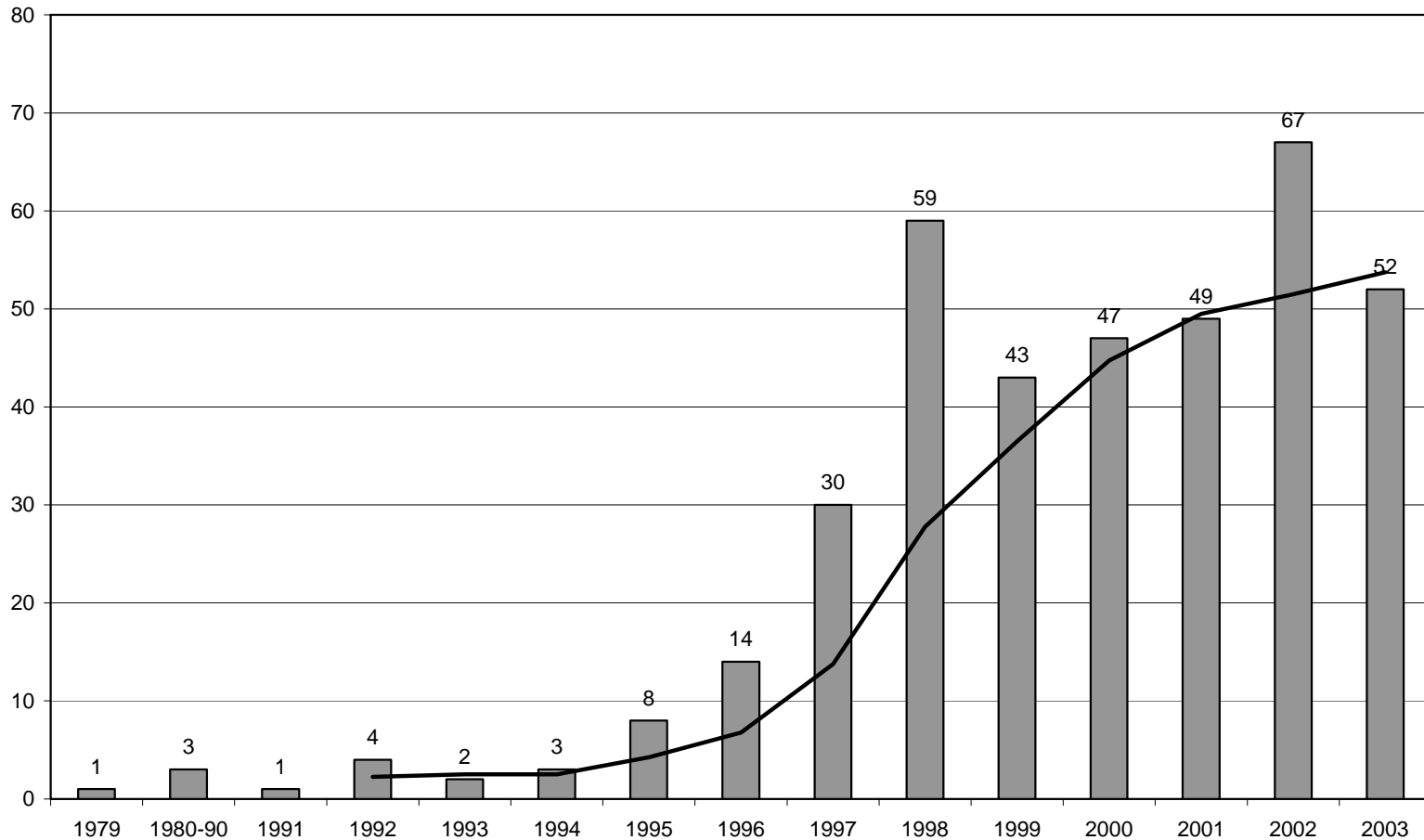
Source: Chris A. Mack, "Down the Silicon Information Highway,"
Semiconductor International, September 1995, 190.

"The lesson to be learned here is simple: Moore's Law is not forever... Given the above scenario for the year 2025, I would say that forcing ourselves to adhere to our current path without economic justification is even more dangerous."

Moore's Law: Literature S-Curve

"Moore's Law" Articles Found in ProQuest

Source: <http://proquest.umi.com/>



ITRS: Moore's Law "Insurance"

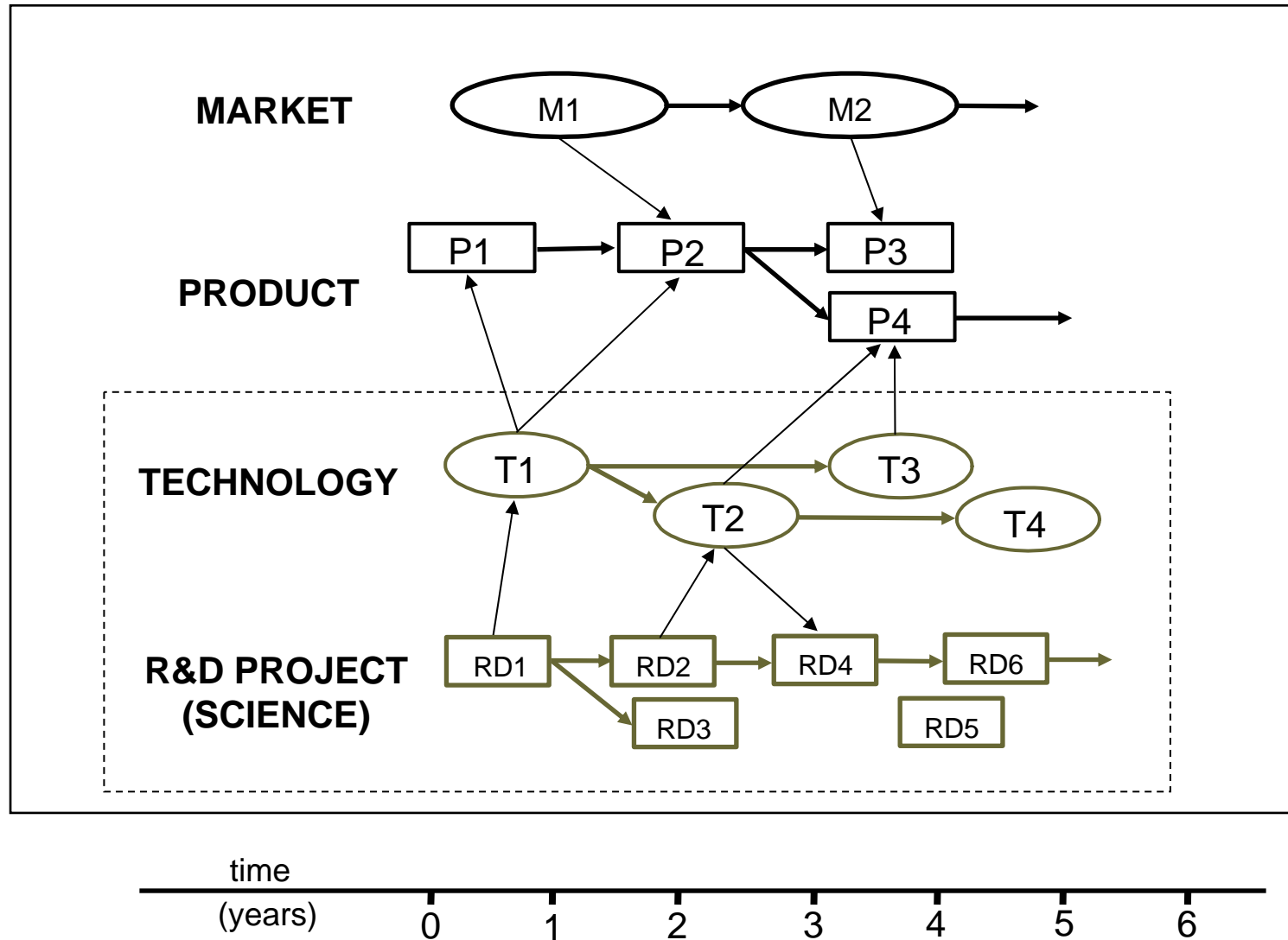
International Technology Roadmap for Semiconductors



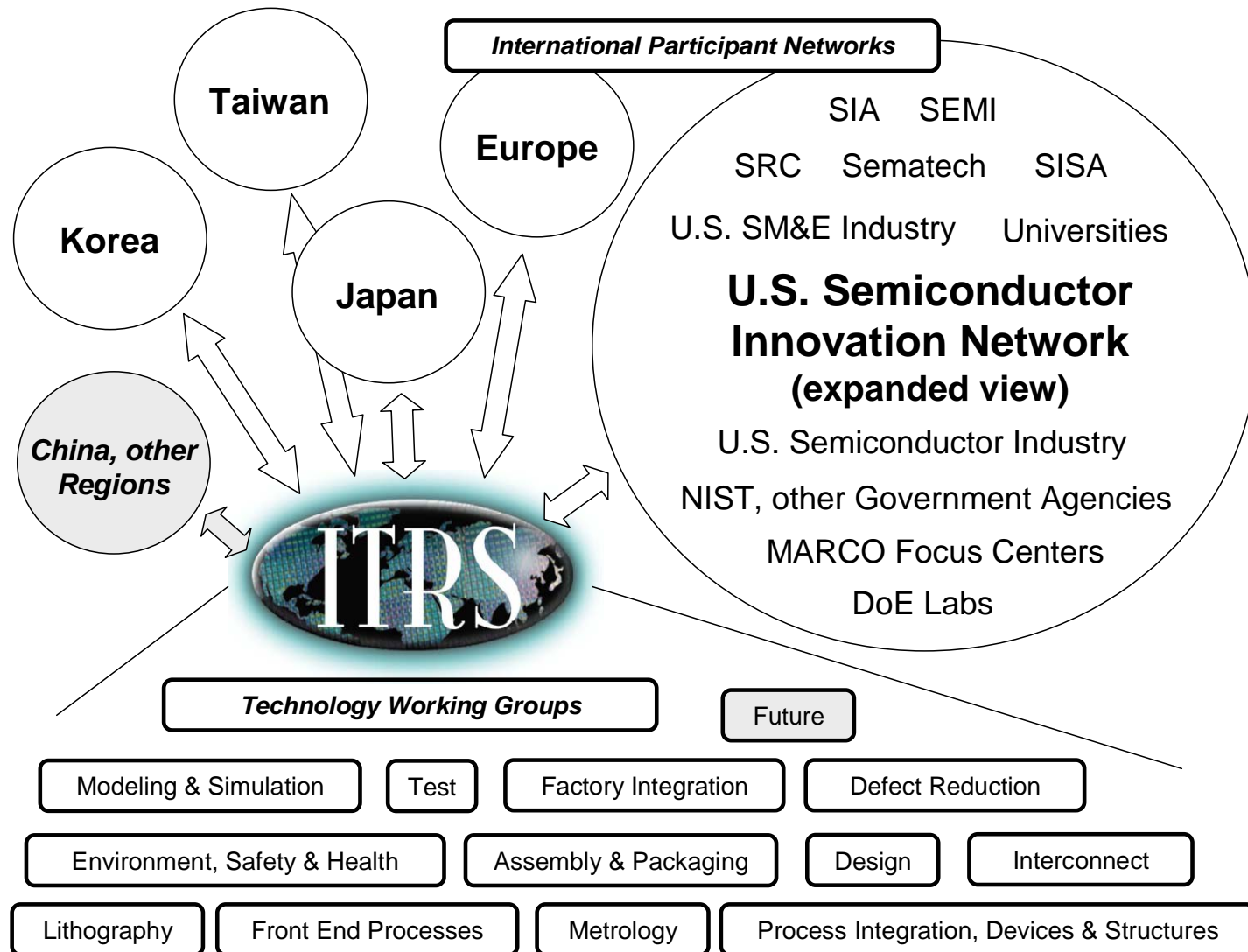
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Generic Roadmap



The ITRS and Organized Innovation



Moore's Law Goes Global

Transition of ITRS

US Domestic

1991
Micro Tech 2000
Workshop Report

1992NTRS

1994NTRS

1997NTRS

1998

World Semiconductor Council

International

2001 ITRS

<http://public.itrs.net>



2000 ITRS
Update

1999 ITRS



1998 ITRS
Update

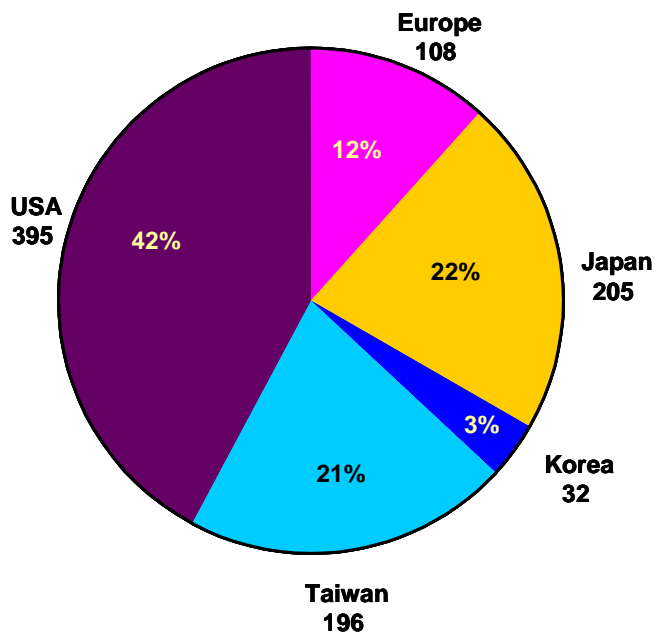
International Technology Roadmap for Semiconductors

ISS Korea 2002, March 22, T. Fukushima

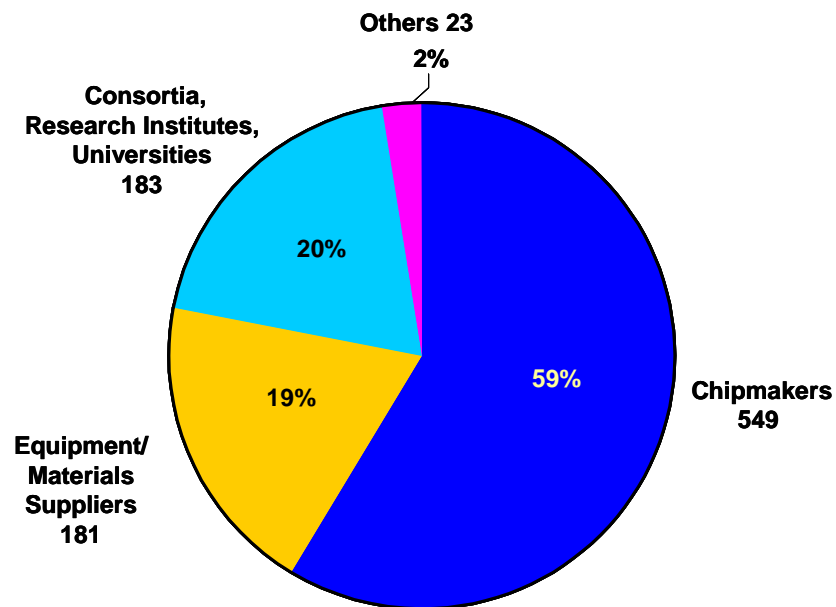


2003 ITRS TWG Demographics

936 Global Participants



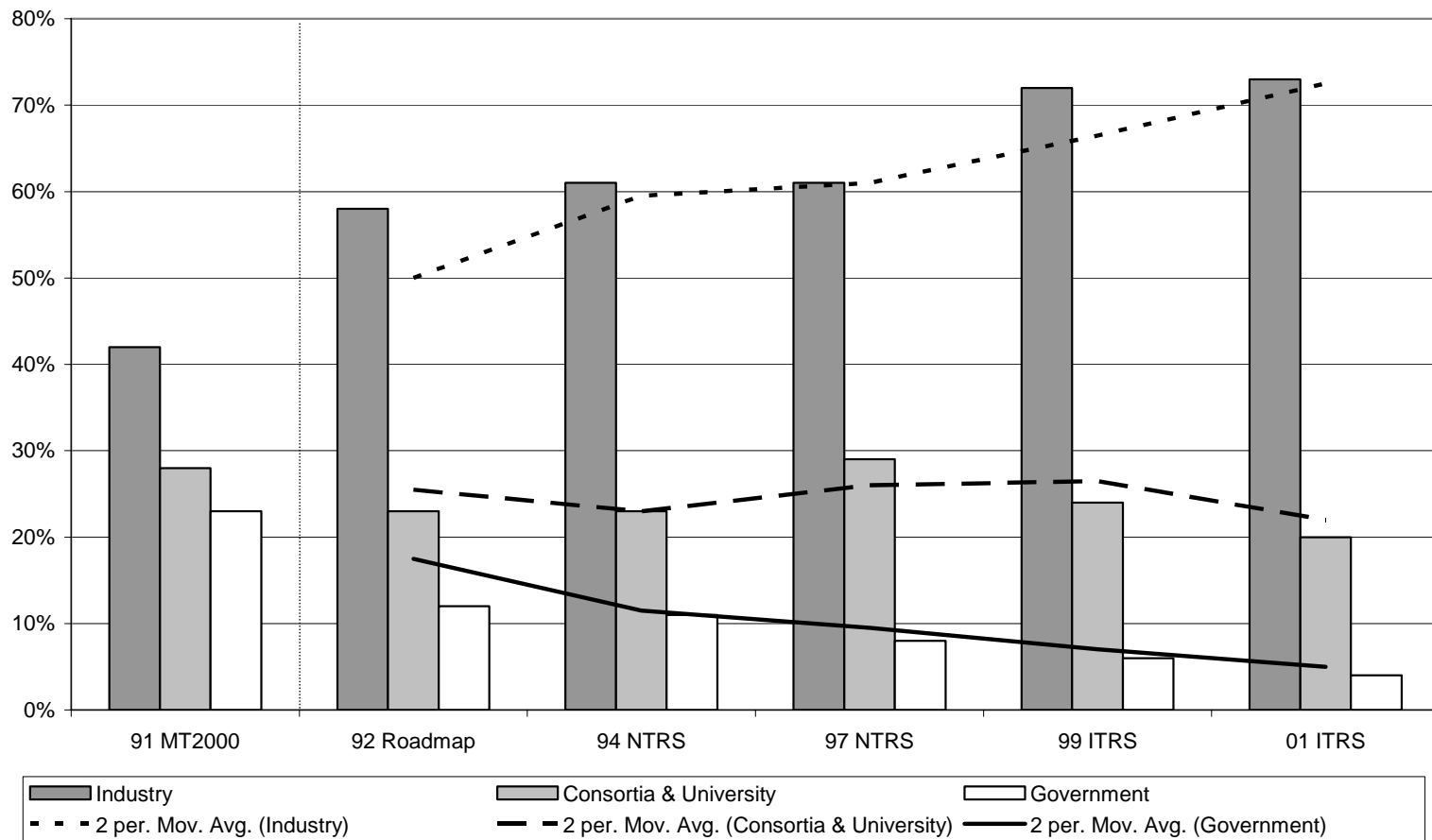
TWG Members by Region



TWG Members by Affiliation

Changing Roadmap Participation Mix

Roadmap Participation Mix
Industry, Consortia & University, Government



ITRS Future Challenges

- Overcoming “red brick wall”
- Path dependency: how to balance on- and off-roadmap innovation
- Caution of becoming too unwieldy and prescriptive
- “Roadmap” may not be the best metaphor (implies certainty)
- Maintaining *voluntary* participation
- Increasing cost of roadmapping